

REINFORCEMENT AND SUBSTITUTION IN HUMANS: A MULTIPLE-RESPONSE ANALYSIS¹

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Three adult human subjects engaged in activities such as reading, sewing, artwork, and candlemaking while living alone in a laboratory apartment 24 hours per day for several weeks. After a baseline period in which the activities were fully available, access to a particular activity (contingent response) was made dependent on engaging in another less-preferred activity (instrumental response). The contingencies produced substantial increases in instrumental responding, and responding decreased toward baseline levels when the dependency was removed. Under the contingent conditions, time earned for the concurrent activity was always less than the baseline level. To determine the contribution of this reduction to the instrumental increase, access to the contingent activity was restricted in the absence of any dependency. The results indicated that increases among responses that filled the newly available time could be selective, *e.g.*, artwork increased when reading was restricted but candlemaking did not. It was concluded that the reductions in the contingent response that accompany contingencies usually do not exclusively determine instrumental increases, but selective increases can contribute to the increase in time devoted to the instrumental response.

Key words: reinforcement, substitution, contingency, restriction, multiple-response, humans

Premack (1959, 1965) expanded the concept of reinforcing events by studying contingencies in which access to one activity (the contingent response) served as a reinforcer for another activity (the instrumental response). His probability differential rule provides an *a priori* basis for specifying the conditions under which one response functions as a reinforcer for another response. According to this rule, a response will be an effective reinforcer for any response with a lower operant probability; the

probabilities can be assessed before the contingency is imposed by the percentage of time devoted to concurrently available responses during a free-access baseline period.

A contingency in which a response of higher probability is dependent on one of lower probability may reduce the level of the contingent response. Under a typical schedule, for example, if the instrumental response continues at its usual level, then time available for the contingent response necessarily will be reduced. Even if the instrumental response increases as a function of the contingency, the increase may not be large enough to restore the contingent response to its baseline level. Thus, increases in time devoted to the instrumental response may occur for at least two reasons: because the response is strengthened by access to the contingent response or, more simply, because there is more time available for instrumental responding.

Premack (1965) reported data from an experiment with rats in which access to drinking was restricted after that response had been successfully used to reinforce running in a wheel. Since the restriction of drinking did not produce increased running, he concluded

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that reduction in the contingent response had not made an independent contribution to the earlier increase. Subsequent research, however, has shown that restriction of one member of a pair of responses may increase the other. Allison and Timberlake (1974) reported that rats drank more of one solution when access to another was restricted, and Dunham (1972) reported increased running when drinking was punished.

Additional complications are created when a restriction is imposed on a repertoire with more than two responses. The newly available time might be distributed proportionately among the remaining responses, according to their relative strengths. On the other hand, relationships might exist within a repertoire of responses such that restriction of one response might increase some members of the repertoire but not others. If the instrumental response happened to be a response subject to this selective effect, then the increase could contribute greatly to increased instrumental performance when the contingency is imposed.

The research described here investigated Premack's analysis of reinforcement as it applies to multiple-response repertoires of human subjects in naturalistic environments. Subjects lived alone in an isolated but comfortable laboratory apartment 24 hr per day for several weeks, engaging in hobbies or other activities of their choosing. Following baseline observations, contingencies were instituted with the instrumental and contingent responses selected in accordance with the probability differential rule. As in Premack's analysis, response strength was measured by the amount of time devoted to each response, rather than by its frequency of occurrence. Following each contingency condition, there was a control condition in which access to the former contingent response was restricted to the amount obtained by instrumental responding under the contingency. The percentage of time devoted to the remaining responses was examined for selective increases that may have resulted from the reduction in the former contingent response. Increases in the former instrumental response observed during the control condition were compared with the increase in instrumental responding produced by each reinforcement contingency. Since there were more than two response alternatives, the newly available time was not restricted to the

former instrumental response, thus allowing study of the contribution of the reduction in the contingent response to the instrumental increase without the constraint of a limited hierarchy.

The research setting was designed to provide minimal interference from outside sources and maximal control of access to specific activities. In this regard, the procedures were similar to those of Findley (1966) and Emurian, Emurian, Bigelow, and Brady (1976), but the present research also differed from these previous studies in several ways. There was no systematic experimental treatment in Findley's research, which was essentially descriptive. The main focus of Emurian *et al.*'s research was on effects of group contingencies on cooperation and social interactions, and all activities were included in the contingency programs. By comparison, the present work examined the influences of reinforcement contingencies on individual performances, and only the two activities involved in the contingency were programmed.

METHOD

Subjects

Newspaper advertisements offering money for participation in a long-term psychology experiment were used to recruit three subjects. The first (HH) was a 19-yr-old female undergraduate student, observed during the summer recess for 21 days. The second subject (BS) was a 26-yr-old male construction worker, unemployed at the time, who also stayed 21 days. The last subject (MLW) was a 39-yr-old housewife, earning money to return to school, who stayed for 34 days. The subjects' interest in the research was financial. The first two were paid \$200.00 for 21 days and the third was paid \$575.00 for 34 days. They did not meet each other nor were they told about the conditions or results of the other subjects. The contract specified that no money would be paid unless the subject stayed the entire time. The only other requirement was observance of restrictions on certain activities. Engaging in a restricted activity was grounds for termination without pay. During the recruiting interview and immediately before the experiment began, the experimenter stated that no other aspects of performance would influence either length of stay or payment.

Apparatus and Living Situation

The subjects lived in a large (7 m by 10 m) comfortably furnished room with no windows to the outside. There were two tables, two chairs, a couch, a single bed, a refrigerator, a hot plate, ample reading materials, a stereo tape recorder for listening to music, and a full complement of cooking, eating, and drinking utensils. A private bathroom was located 8 m down an isolated hallway. Subjects lived alone 24 hr per day; they left the main room only to go to the bathroom. For the first subject (HH), the lights were turned on and off at her request, allowing her to determine the length of each waking period. For the second and third subjects, the cycle was fixed at 15 hr light and 9 hr dark. Although there was no clock, radio, TV, phone, or mail, all standard services necessary for living (*e.g.*, fresh food, laundry) were provided, and there was always enough material for all activities (*e.g.*, magazines for reading, paper for drawing).

The living area could be viewed through one-way mirrors from two adjoining smaller control rooms. A two-way intercom, lighting, and temperature of the area were under control of the experimenter. Each response was simultaneously recorded on an Esterline-Angus event recorder and a timer that accumulated the total time spent on the response. A panel of labelled red lights in the subjects' room was used to indicate restriction of access to any response. Most of the subjects' questions were answered with a "yes" or "no", but longer answers were given on a few occasions. In the control area was a videotape system that could make complete records of 60-min segments of

behavior. Additional details are given elsewhere (Bernstein, 1974).

Response Categories and Observation

Each subject selected several hobbies to engage in during the time in the laboratory, and the time devoted to these activities was observed and recorded. Response categories were defined in terms of body position and contact with appropriate materials. For example, "sewing" was recorded if the subject was touching any cloth, thread, patterns, or equipment designated for sewing, and the subject's head was directed toward the materials. Similarly, "reading" was recorded if the subject was looking at and holding a copy of the reading matter. Table 1 lists the categories for each subject and those categories common to all three subjects. These categories were mutually exclusive of each other, except that Subject MLW could satisfy the definitions of reading and knitting at the same time and all subjects could be eating or drinking while engaging in other activities. The subject's location in the room also was recorded.

An observer was present 24 hr per day, but recording was conducted only during the 15 hr when the living area was illuminated. One observer did 95% of the recording and five others did the remainder. Whenever the definition for a response category was met, the observer activated both the event recorder and the timer by pressing a switch.

Reliability of observation was assessed both within and between observers using videotape reviews of selected observation periods. Reliability coefficients were calculated as the percentage of 1-min intervals in which

Table 1
Response Categories

<i>Subject HH</i>	<i>Subject BS</i>	<i>Subject MLW</i>	<i>Common to all Subjects</i>
Sewing	Artwork	Sewing	Food preparation
Embroidery	Reading <i>Hot Rod</i>	Embroidery and needlepoint	Eating
Reading <i>Scientific American</i>	Reading <i>National Geographic</i>	Knitting	Drinking
Reading fiction	Reading <i>Reader's Digest</i>	Studying Russian	Maintenance
	Candlemaking	Reading <i>Scientific American</i>	Exercise
		Reading <i>National Geographic</i>	Writing
		Reading stories	
		Reading women's magazines	
		Sketching and drawing	
		Oil painting	
		Playing cards	

two observers or two records made by one observed agreed on the activity to be scored. Subjects typically spent long uninterrupted periods on one response, but samples were selected that included several changes in behavior so that reliabilities would not be inflated. Percentages of agreement for all observers and all responses except eating and drinking were above 95%, and most were 99%. Eating and drinking were not used in the reinforcement procedures.

Procedure

Before the experiment began, each subject spent several hours moving in personal belongings and becoming familiar with the laboratory and the procedure for restricting activities. Assurance was given that participation could be terminated at anytime. Two subjects terminated their participation early in the experiment, and their data are not included here. Since some activities tended to occur only in certain portions of the waking periods, an entire observation period was included in each data point to assure that each contained a complete cycle of activity. The data for the second two subjects (BS or MLW) are presented in points that exactly represent the 15 hr of observation during a standard period of illumination of the subject area. The first subject (HH) determined the light-dark cycle, however, and it was not regularly 15 hr. Her data are presented in points representing 16 or 20 hr, so that each point included an entire daily cycle of activity.

Free-operant baseline. The relative time devoted to the various responses was assessed during an initial baseline condition, lasting several days. There were no restrictions on how subjects could spend their time. The rank order of responses during the free-operant conditions was used to select the responses to be used in the reinforcement conditions. There was also a baseline period between conditions, except for the first subject (HH), who did not have a baseline period between the reinforcement and control conditions.

Reinforcement contingency. After the baseline condition, an activity with a low operant probability was selected as the instrumental response, and an activity with a higher operant probability was selected as the contingent response. Performance of the instrumental response was required to gain access to the con-

tingent response. To earn the amount of time formerly spent on the contingent response, a subject was required to increase the time formerly spent on the instrumental response. The amount of increase can be expressed as the ratio between the amount of instrumental responding required to restore the baseline level of the contingent response and the baseline level of the instrumental response (the instrumental ratio). For example, the subject may have been required to double the baseline time of the instrumental response to maintain the contingent response at its baseline level. If during the baseline condition the instrumental response had occupied 25% of the time and the contingent response 40% of the time, then a contingency with a 2:1 instrumental ratio requires that 50% of the time be spent on the instrumental response to maintain the contingent response at 40%. Contingencies constructed in this manner assured that the time available for the contingent response was below the baseline level if the instrumental response remained at its baseline level.

The schedule provided that a constant amount of access to the contingent response followed completion of a specified period of instrumental responding. The restriction light for the contingent response went off only when the required amount of instrumental responding was completed; further instrumental responding did not increase the time earned for the contingent response. There was a fixed amount of time available to be devoted to the contingent response, but the time did not have to be used immediately. The subject could engage in the response several times for short durations or use the earned time in one continuous burst. After the time for the contingent response was expended, the restriction light came on again, indicating that the response was restricted once more. Thus, the schedule ensured that the subjects alternated between the instrumental and contingent responses several times each day, first completing the instrumental requirement and then using the time earned for the contingent response.

Within the limits of the ratio between the instrumental and contingent responses, the specific durations of the period of required instrumental performance and periods of availability of the contingent responses were

matched to the length of a typical burst of the contingent response during the baseline condition. For example, during the baseline condition Subject MLW typically engaged in the contingent response (sewing) in continuous 35-min bursts, so the first contingency provided 35-min periods of access to sewing. The schedule imposed required slightly more than twice that amount of the instrumental response (reading), so the instrumental requirement was 71 min of reading.

At the beginning of the contingency condition, the experimenter entered the laboratory and told the subjects that access to a given activity depended on engaging in another activity. The two activities were described, examples were given, and the name of the restricted activity was placed on the signal board next to the light, which indicated when the response was unavailable. Subjects were not told the duration of the instrumental requirement or the amount of the contingent response earned each time. They were told that the light would go off when they had satisfied the instrumental requirement and that it would go on again when they had used the time earned. Whenever the restriction light was turned on or off, the room lights were dimmed for 1 to 2 sec to alert subjects to the change. Finally, subjects were told that they were not required to remove the restriction and could engage in other activities instead.

The details of the reinforcement contingencies for all subjects are found in Table 2. In addition to listing the activities used as the instrumental and contingent responses, the table indicates the amount of instrumental responding required for obtaining each period of access to the contingent response and the amount of time earned for the contingent response. Also shown in Table 2 are the instrumental ratios for restoration of the contingent response to its baseline level. The instrumental ratios varied over the experiment, as attempts were made to increase the size of the reinforcement effects, but each ratio was sufficient to require an increase in instrumental responding.

Table 2 also presents the sequence and duration of all conditions for which data will be presented. Data from nine days for Subject BS and 12 days for Subject MLW are not relevant to the present analysis and are not re-

ported here (see Bernstein, 1974). Condition durations were often limited by the length of each subject's commitment to stay, and for Subject BS, the second contingency condition was a replication of the first because there was not sufficient time to run a new contingency condition and a control restriction.

Matched-control restriction. For each contingency condition there was a matched-control condition, in which response-independent periods of access to the former contingent response were scheduled, so that the time devoted to the contingent response equalled the amount earned by instrumental responding in the contingency condition. In the example described above, suppose that a subject earned only 30% availability of the contingent response by increasing instrumental responding to 37.5%, rather than the required 50%. In the matched-control condition, response-independent periods of access to the contingent response would be given so that the time spent on that response was 30%. The lengths of these periods of noncontingent access were matched to the time periods that occurred during the contingency condition. The spacing of each access period was not matched to the times from the contingency condition, however, and the sequence of periods was scheduled with a random number table.

Before this condition, the experimenter entered the laboratory and explained that the restriction light would be going on and off in a random pattern. The subjects were told that changes in the restriction were unrelated to time spent on the former instrumental response. Each matched-control condition was the same length as the contingency condition preceding it, except that the second matched-control condition for Subject HH lasted 15 hr longer than the contingency condition.

Criteria for termination of conditions. The duration of each condition was determined in large part by the length of each subject's stay in the laboratory, which was agreed on before the experiment began. Because of this practical limitation it was not possible to continue each condition until performances were stable. Instead, the focus was on changes in the level of instrumental performance from one condition to another, rather than on determining asymptotic levels of performance; changes from baseline to contingency conditions were replicated between and within subjects.

Table 2
Details and Sequence of Conditions of All Subjects

Condition	Duration in Hours	Instrumental Response	Contingent Response	Instrumental Requirement in Min	Allotment of Contingent Response in Min	Instrumental Ratio ^a
<i>Subject HH</i>						
Baseline 1	60	—	—	—	—	—
Contingency 1	60	Reading <i>Scientific American</i>	Sewing	33	43	2.4:1
Matched Control 1	40	—	Sewing	—	43	—
Baseline 2	32	—	—	—	—	—
Contingency 2	32	Reading <i>Scientific American</i>	Reading fiction	64	40	1.9:1
Matched Control 2	48	—	Reading fiction	—	40	—
Baseline 3	16	—	—	—	—	—
<i>Subject BS</i>						
Baseline 1	45	—	—	—	—	—
Contingency 1	30	Artwork	All reading	70	45	7.6:1
Baseline 2	15	—	—	—	—	—
Matched Control	30	—	All reading	—	45	—
Baseline 3	15	—	—	—	—	—
Contingency 2	30	Artwork	All reading	70	45	7.6:1
Baseline 4	15	—	—	—	—	—
<i>Subject MLW</i>						
Baseline 1	60	—	—	—	—	—
Contingency 1	60	Reading <i>National Geographic and Scientific American</i>	All sewing	71	35	5.1:1
Baseline 2	15	—	—	—	—	—
Matched Control 1	60	—	All sewing	—	35	—
Baseline 3	15	—	—	—	—	—
Contingency 2	45	Studying Russian	Sewing and knitting	45	47	3.6:1
Baseline 4	15	—	—	—	—	—
Matched Control 2	45	—	Sewing and knitting	—	47	—
Baseline 5	15	—	—	—	—	—

^aRatio between the amount of instrumental responding required to restore baseline level of contingent response and the baseline level of the instrumental response.

For each subject there was a rough plan of the duration of each condition that fit the time available, but alterations of this plan were made when warranted. When the data showed changes in instrumental performance in the predicted direction that were well above the baseline range (during a contingency condition) or well within the baseline range (during a return to baseline), the condition was terminated. If there was no clear change during the first two days of a contingency condition, it was continued for the planned duration. If in the baseline condition the free-operant level had changed, then that condition was continued for two or three days to establish a new operant level. With the exception noted above, each matched-control

condition lasted the same time as the contingency condition that preceded it.

RESULTS

The results are presented first in terms of the effects of the contingency operation on the instrumental and contingent responses, and second, in terms of the effects of the matched-control condition on all responses.

Instrumental and Contingent Performances

The measure of primary interest was the percentage of time devoted to the instrumental and contingent responses. Figure 1 shows the percentage of time devoted to the two types of responses by Subject HH. The instru-

mental response (reading *Scientific American*) increased to a level outside the range of baseline values for that response during the two contingency conditions shown. The two contingent responses (sewing in the top panel and reading fiction in the bottom panel) were not restored to their baseline levels by instrumental performance during the contingency conditions. The instrumental response did not increase during the first matched-control condition, but there was a small increase in the average level of performance in the second matched-control.

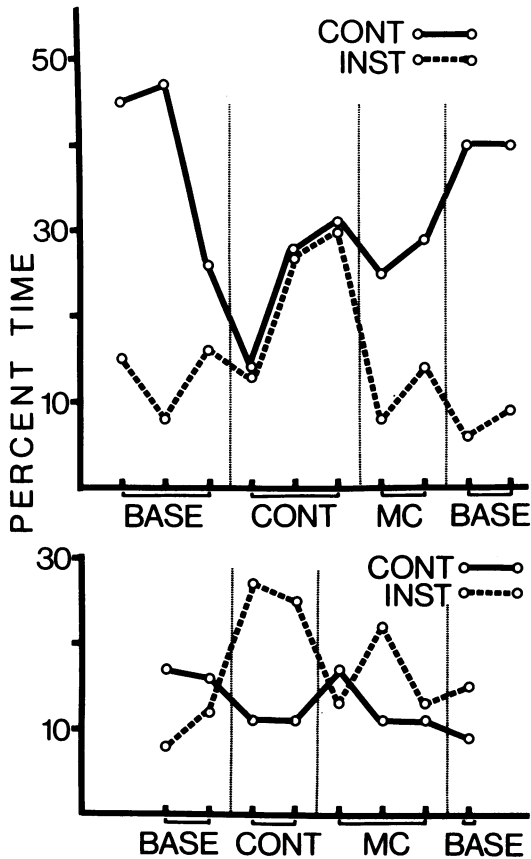


Fig. 1. Top: percentage of time devoted to reading *Scientific American* (instrumental response) and to sewing (contingent response) during baseline (BASE), contingency (CONT), and matched-control (MC) conditions for Subject HH. First eight points are 20 hr each; last two points are 16 hr each. Bottom: percentage of time devoted to reading *Scientific American* (instrumental response) and to reading fiction (contingent response) during baseline (BASE), contingency (CONT), and matched-control (MC) conditions for Subject HH. Each point is 16 hr. The last baseline in the top portion represents the same 32 hr of observation as the first baseline in the bottom portion.

Figure 2 shows the percentage of time devoted to the two responses by Subject BS. The instrumental response (artwork) increased to a level above the range of its baseline values during the two contingency conditions. It may also be seen that the contingent response (all reading, in both cases) was not restored to its baseline level by instrumental performance during the contingency conditions. The instrumental response also increased to a level well above the baseline values during the matched-control condition, although the increase was smaller than that observed during the contingency condition.

Figure 3 shows the percentage of time devoted to the instrumental and contingent responses by Subject MLW. Both instrumental responses (reading *Scientific American* and *National Geographic* in the top panel, and studying Russian in the bottom panel) increased during the contingency conditions to levels higher than the average of the baseline values. The contingent responses (all sewing in the top panel, and sewing and knitting in the bottom panel) were not restored to their baseline levels by instrumental performance during the contingency conditions. During the matched-control condition, the first instrumental response (reading *Scientific American* and *National Geographic*) also increased to a level above the average of the baseline values, but the increase was smaller than that observed during the contingency condition. The second instrumental response did not increase during the matched-control period.

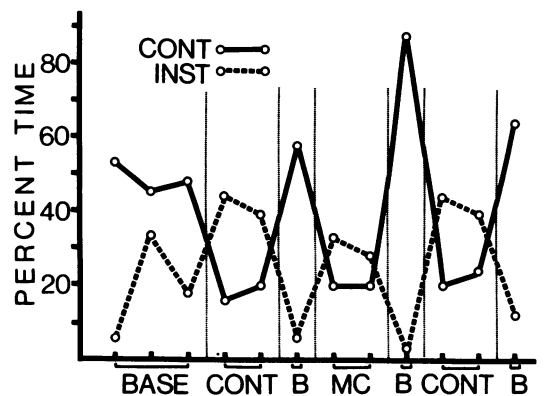


Fig. 2. Percentage of time devoted to artwork (instrumental response) and to reading (contingent response) during baseline (BASE or B), contingency (CONT), and matched-control (MC) conditions for Subject BS. Second contingency condition was a replication of the first. Each point is 15 hr.

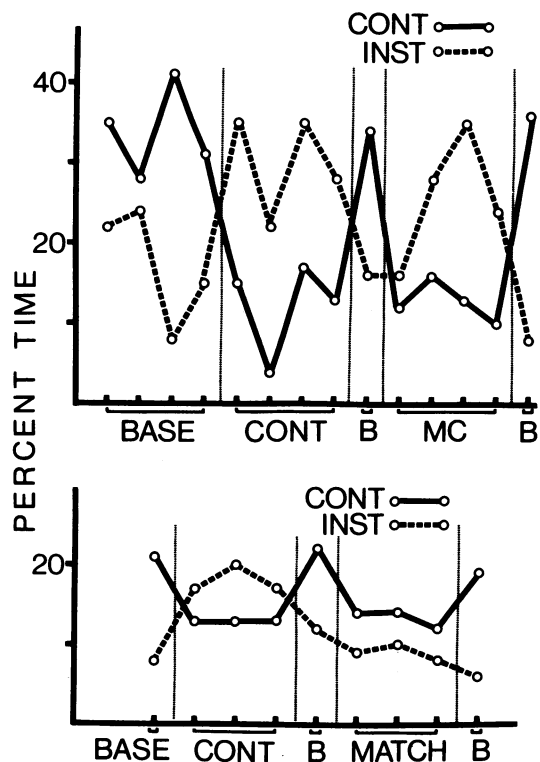


Fig. 3. Top: percentage of time devoted to reading *Scientific American* and *National Geographic* (instrumental response) and to all sewing (contingent response) during baseline (BASE or B), contingency (CONT), and matched control (MC) conditions for Subject MLW. Each point is 15 hr. Bottom: percentage of time devoted to studying Russian (instrumental response) and to sewing and knitting (contingent response) during baseline (BASE or B), contingency (CONT), and matched control (MATCH) conditions for Subject MLW. Each point is 15 hr. The last baseline in the top portion represents the same 15 hr of observation as the first baseline in the bottom portion.

To summarize, in all six of the contingency conditions performance of the instrumental response increased to levels well above the baseline performance of the same response. In all cases, the instrumental response decreased when the contingency was removed during subsequent baseline conditions, thus confirming that the increases were due to the experimental intervention. The amount of time earned for the contingent response always was lower than the baseline level of the contingent response, and this effect also diminished when the contingency was removed, with the exception of the last baseline condition for Subject HH (Figure 1, bottom panel). Instrumental responding during the

matched-control conditions typically was lower than in the contingency conditions. In three cases, the level of the former instrumental response during restriction was within the range of its baseline values. However, for Subject BS (Figure 2) and for the first matched-control condition for Subject MLW (top portion of Figure 3), the former instrumental response increased to levels above the range of its baseline values. In both cases, the response returned to its baseline level when the restriction on the former contingent response was ended, suggesting that the effect did not result from a change in the baseline level of the response.

Effects of the Matched-Control Restriction on Response Substitution

The restriction of one activity in the matched-control conditions provided information about substitution for the restricted activity by the remaining activities. When one response is restricted, the time devoted to other activities necessarily increases, simply because more time is available. If substitution for the restricted activity is unselective, then the newly available time should be distributed proportionately among the remaining responses according to their operant levels. Such a redistribution would preserve the ratios among the activities and their rank order. Selective substitution refers to instances in which an unrestricted activity increases more than would be expected by a proportional redistribution.

All three subjects showed selective increases as a result of the restrictions. Table 3 gives four examples of responses that increased more than expected during the matched-control condition. For each response, the table shows the mean percentage of time devoted to the response during baseline sessions and during the matched-control sessions, along with the range of average daily values. During the first matched-control condition for Subject HH, in which sewing was the restricted response, the share of time devoted to embroidery increased from 6% to 22%, instead of to the expected value of 8%, and its rank was raised from fourth to second. During the matched-control condition for Subject BS, in which reading was the restricted response, art-work increased from 12% to 29%, instead of to the expected value of 23%. During the first

Table 3

Observed and expected redistributions of per cent time and rank orders of remaining activities.

Subject	Response	Expected			Baseline Rank Order	Matched Control Rank Order
		Per Cent Time in Baseline (and Range)	Proportional Redistribution of Time in Matched Control	Per Cent Time in Matched Control (and Range)		
HH	Embroidery	6 (0-15)	8	22 (19-25)	4	2
BS	Artwork	12 (0-33)	23	29 (28-31)	2	2
MLW	Reading Nat. Geog. & Sci. Am.	14 (6-25)	19	27 (16-38)	3	1
MLW	Needlepoint	9 (0-18)	10	17 (7-30)	5	2

matched-control condition for Subject MLW, in which sewing was the restricted response, reading magazines increased from 14% to 27%, instead of to the expected value of 19%, and its rank was raised from third to first. During the second matched-control condition for Subject MLW, in which sewing and knitting were the restricted responses, needlepoint increased from 9% to 17%, instead of to the expected value of 10%, and its rank was raised from fifth to second.

It is possible that these selective increases reflected only local or random fluctuation and did not represent a mutual substitutability between the activities. To see if the inverse covariation between the activities was consistently present throughout the experiment, a product-moment correlation coefficient was calculated between time devoted to the restricted response and time devoted to the response that increased selectively, using data from the time periods represented by the points in the figures. The analysis excluded periods in which the relation between the two responses was constrained by the experimental procedure (*i.e.*, when the response showing an increase was the instrumental response in a contingency), and a separate correlation was calculated for each subject and each pair of responses. For the four instances of substitution shown in Table 4, the correlations over the entire experiment were substantial: -0.82 ($n = 16$), -0.83 , ($n = 17$), -0.76 ($n = 15$), and -0.71 ($n = 11$) respectively. As a comparison, similar correlations were calculated for pairs of activities that did not substitute for each other in the matched-control condition, and in all comparisons the correlations were substantially lower. The correlation between sew-

ing and fiction reading for Subject HH was -0.17 ($n = 13$), between reading and candle-making for Subject BS was -0.11 ($n = 21$), and between sewing and reading stories for Subject MLW was -0.26 ($n = 24$). These analyses show that the mutual substitution was a reliable phenomenon.

Five other activities also increased during the matched-control condition, but only to levels expected by the proportional redistribution. These increases were small in comparison to the selective increases, so overall proportional increases would not contribute much to increases in instrumental responding. The range of increases in the five responses was 3% to 7% (mean = 4.2%), while the expected proportional increases ranged from 1% to 7% (mean = 4.0%).

DISCUSSION

The present results provide evidence that the reinforcement relations among ordinary human activities can be described by Premack's (1959, 1965) formulation. While some research has been done on this topic with humans (*e.g.*, Ayllon and Azrin, 1968; Lattal, 1969), the present study included systematic replication of the effect and a control restriction on the contingent response.

The increases in the instrumental response never were sufficient to restore the contingent response to its operant level. Allison (1976) pointed out that this result can be artifactual if the sum of the required amount of instrumental responding and the baseline amount of contingent responding exceeds the length of the experimental sessions. In three of the six contingency conditions of the present ex-

periment, it was easily possible for the subject to restore the contingent response to its baseline level; for the other three it was not (both contingency conditions for Subject BS and Contingency 1 for Subject MLW). It is unlikely, however, that time limitations directly influenced performance, since subjects devoted less total time to the instrumental and contingent responses during the contingency periods than during baseline.

Although the data from only six contingency conditions are inadequate for a serious test of models that predict the levels of instrumental and contingent performance, one qualitative prediction from such models can be assessed. Both a value averaging model (Mazur, 1975) and a conservation model (Allison, 1976) predict a facilitation of the instrumental response and a suppression of the contingent response. This prediction was confirmed in every contingency condition.

There were instances in which one response substituted for another when it was restricted; such pairs also showed an enduring negative correlation across the entire experiment. The extent of mutual substitution may be a function of the way response classes are defined. In order to break up the continuous stream of behavior into comparable response classes, the characteristics of each class of responses must be specified, and various criteria can be used, such as response topography, operation of a manipulandum, systematic covariation, or inferred motivational characteristics. Whatever the basis for the categories, the system is necessarily somewhat arbitrary, and different systems could produce response repertoires with very different characteristics. Consider a set of typical human activities such as sewing, artwork, reading, and embroidery. If contact with the various objects (*e.g.*, sewing machine, paintbrush, book, and needle) were used to define the response classes, a set of activities that would have a selective substitution pattern would probably result, with sewing and embroidery replacing each other during restrictions. On the other hand, if the presence of a negative covariation across days during baseline observation were used to define the response classes, sewing and embroidery would likely become a meta-category, and a hierarchy of activities without substitution would result.

The matched-control condition was designed to reveal the extent to which instrumental in-

creases were simply a result of restricting the contingent response, and two such increases were observed (artwork for Subject BS and reading magazines for Subject MLW). This finding points to the importance of the way response classes are defined and responses selected for use in the contingencies. Should the instrumental and contingent responses happen to be substitutable activities, the reduction in the contingent response can make a potent contribution to the instrumental increase. When the instrumental and contingent responses are activities that do not substitute for each other, the instrumental increase can be attributed solely to the contingency between the two responses. The appropriate conclusion suggested by the present findings is that a reduction in the contingent response usually does not exclusively determine an instrumental increase, but under the special conditions described above it can add to the increase in instrumental responding under a contingency.

Interactions between the experimental results and definitions of response class boundaries pose problems for the study of reinforcement in behavioral repertoires that include several different response alternatives. There is a need to assess the patterns of substitution among the response classes used in a multi-operant setting, or to construct a set of response classes that have a substitution pattern compatible with the research goals. If there are *a priori* theoretical or practical reasons for using certain response-class definitions, then the substitution pattern should be assessed during the research to aid in interpreting the results. If, on the other hand, the research is to be generalized to hierarchies with a known substitution pattern (selective or proportional), then response-class boundaries should be altered until a repertoire with the desired pattern is created for use in the research.

The present research studied ordinary human activities continuously in a naturalistic setting, and as such, it differs from studies using responses such as lever pressing (*e.g.*, Eisenberger, Karpman, and Trattner, 1967; Hake, Olvera, and Bell, 1975; Matthews, Shimoff, Catania, and Sagvolden, 1977). With an increase in the number and type of response alternatives and with considerably longer experimental periods, the present procedure allowed analysis of complex human behavior.

The procedure was limited by the extensive time required to collect the data. Because of these time limitations, stable levels of performance could not always be determined; nor was it possible to replicate reinforcement conditions with several different instrumental ratios to determine maximum instrumental increases for a given pair of responses. Despite these problems, there was sufficient order in the data to draw some conclusions about the specification of reinforcing events and the effect of reduction in the contingent response. Further research on human behavior with these procedures seems warranted.

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